PROGRESS OF THE RERTR PROGRAM IN 2001

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ABSTRACT

This paper describes the 2001 progress achieved by the Reduced Enrichment for Research and Test Reactors (RERTR) Program in collaboration with its many international partners.

Postirradiation examinations of microplates have continued to reveal excellent irradiation behavior of U-Mo dispersion fuels in a variety of compositions and irradiating conditions. Irradiation of two new batches of miniplates of greater sizes was completed in the ATR to investigate the swelling behavior of these fuels under prototypic conditions. These materials hold the promise of achieving the program goal of developing LEU research reactor fuels with uranium densities in the 8-9 g /cm^3 range.

Qualification of the U-Mo dispersion fuels has been delayed by a patent issue involving KAERI. Test fuel elements with uranium density of 6 g/cm^3 are being fabricated by BWXT and are expected to begin undergoing irradiation in the HFR-Petten reactor around March 2003, with a goal of qualifying this fuel by mid-2005. U-Mo fuel with uranium density of 8-9 g/cm^3 is expected to be qualified by mid-2007.

Final irradiation tests of LEU ^{99}Mo targets in the RAS-GAS reactor at BATAN, in Indonesia, had to be postponed because of the 9/11 attacks, but the results collected to date indicate that these targets will soon be ready for commercial production. Excellent cooperation is also in progress with the CNEA in Argentina, MDSN/AECL in Canada, and ANSTO in Australia.

Irradiation testing of five WWR-M2 tube-type fuel assemblies fabricated by the NZChK and containing LEU UO_2 dispersion fuel was successfully completed within the Russian RERTR program. A new LEU U-Mo pin-type fuel that could be used to convert most Russian-designed research reactors has been developed by VNIINM and is ready for testing.

Four additional shipments containing 822 spent fuel assemblies from foreign research reactors were accepted by the U.S. by September 30, 2001. Altogether, 4,562 spent fuel assemblies from foreign research reactors had been received by that date by the U.S. under the FRR SNF acceptance policy.

The RERTR program is aggressively pursuing qualification of high-density LEU U-Mo dispersion fuels, with the dual goal of enabling further conversions and of developing a substitute for LEU silicide fuels that can be more easily disposed of after expiration of the U.S. FRR SNF Acceptance Program. As in the past, the success of the RERTR program will depend on the international friendship and cooperation that has always been its trademark.

1. Introduction

The 2001 event that will undoubtedly stand longest in our memory is the terrorist attack that destroyed the World Trade Center in New York, and killed thousands of its occupants, on September 11, 2001. The RERTR program was immediately and directly affected by that event, because the resulting international reaction forced the cancellation of the 2001 International RERTR Meeting that had been planned to occur in Bali, Indonesia, on October 21-25, 2001. We are very grateful to the organizers of RRFM 2002 for providing us with a forum at which several of the papers originally meant for Bali can be presented.

More important for the RERTR program than the cancellation of the meeting, the September 11 attack has caused a paradigm shift in the way we view our work and our goals. In the past, our main concern was that rogue nations or terrorist groups would develop nuclear weapons and that, by threatening to use those weapons, they would secure for themselves political and economic advantages that could drastically alter the world balance of power. September 11 changed this view of the threat facing us. Today we know that if a nuclear weapon were to fall in the hands of those who organized the September 11 attacks there would be no threats and no negotiations. Millions of innocent victims would die in a flash, without warning, killed by people driven by a twisted ideology and devoid of any respect for human life, including their own.

It is with this terrible vision in mind that we must face the task ahead of us: how to remove from civilian traffic any amount of highly enriched uranium that a terrorist could use to manufacture an explosive device. Achieving this goal will eliminate one of the most dangerous pathways that a terrorist could follow. Much progress has been accomplished towards this end since 1978, when the RERTR program began. This progress has been the result of a concerted effort by many international organizations involved with research reactors, including fuel and target developers, fabricators, regulators, shippers and, especially, reactor organizations. In close collaboration with this international community, the RERTR program will pursue with increased urgency the goal of eliminating civilian use of highly enriched uranium.

2. Status and progress of the RERTR program

The main events, findings, and activities of the RERTR Program are summarized below, with special emphasis on those that have occurred since the Las Vegas International RERTR Meeting [1].

1. Reprocessing studies at the Savannah River Site (SRS) concluded in 1983 that RERTR silicide fuels could be reprocessed there. These results were rendered moot, however, by DOE's decision to phase out reprocessing at SRS and by the expiration of the Off-Site Fuel Policy at the end of 1988. A new DOE policy was issued in 1996 [2] allowing, until May 2009, the return of spent research reactor fuel elements of U.S. origin irradiated before 13 May 2006.

   Implementation of this policy through the U.S. Foreign Research Reactor Spent Nuclear Fuel (FRR SNF) Acceptance Program has been very successful [3]. In particular, between October 1, 2000, and September 30, 2001, four additional shipments of spent research reactor fuel containing 822 MTR-type elements were received at the SRS. With these additional shipments, 3,727 MTR elements had been received at SRS and 835 TRIGA elements had been received at INEEL by September 30, 2001, under the FRR SNF Acceptance Program, for a total of 4,562 elements.

   Many research reactors intend to send their spent fuel to the COGEMA plant in La Hague, France after expiration of the FRR SNF Acceptance program, but COGEMA has indicated that it cannot accept significant amounts of silicide fuel in its present plant configuration. Some options for coping with this issue are addressed later in this paper.

2. A fundamental activity of the RERTR program has always been the development and qualification of safe LEU fuels that can replace HEU fuels without significant performance or economic penalties. The qualified uranium densities of the three main fuels which were in operation with HEU in research reactors when the program began were first increased significantly with LEU (UAl_x-Al, from 1.7 g/cm^3 to 2.3 g/cm^3; U_3O_8-Al from 1.3g/cm^3 to 3.2 g/cm^3; and $UZrH_x$, from 0.5 g/cm^3 to 3.7 g/cm^3). A new LEU fuel type, based on U_3Si_2-Al was also developed and qualified with uranium densities up to 4.8 g/cm^3. This fuel type has been internationally accepted and is fabricated routinely for more than twenty research reactors by several international fuel fabricators.

   The effort to develop new advanced LEU fuels with higher effective uranium loadings was restarted in 1996 after a pause of about six years. Three batches of 32 microplates each, containing a variety of promising fuel materials, were irradiated between 1997 and 1999 in the Advanced Test Reactor (ATR) in Idaho. Postirradiation examinations indicated very promising behavior of U-Mo alloy particles dispersed in an aluminum matrix, with Mo content between 6% and 10% and uranium densities up to 8-9 g/cm^3.

   Irradiation of two new nearly identical batches of plates, RERTR-4 and RERTR-5, containing 32 positions each and planned to reach 80% and 50% burnup, respectively, began in 2000 and was completed in September 2001. The plates have larger dimensions than those used in prior experiments, have uranium densities of either 6 g/cm^3 or 8 g/cm^3, and are intended to investigate the swelling behavior of U-Mo dispersion fuels under a variety of realistic operating conditions. Two of the plates have solid U-Mo [4] meat, to investigate the feasibility of using this concept in research reactor plates. Results to date of the postirradiation examinations of RERTR-5 (50% burnup) are reported at this meeting [5], while examinations of RERTR-4 (80% burnup) have recently begun. The activities related to U-Mo dispersion fuels are conducted in close collaboration with a parallel French fuel development program [6,7]. In general, all results collected to date are consistent with the view that low-enriched U-Mo dispersion fuels can be used successfully in research reactor fuels with very high uranium densities.

3. The effort to qualify U-Mo dispersion fuel with high uranium densities has been divided into two parts. An initial effort to qualify U-Mo fuel with uranium density of up to 6 g/cm^3 is aimed at preventing potential disruptions in the operation of research reactors currently operating with LEU silicide fuel due to lack of a method to dispose of their spent fuel after termination of the FRR SNF Acceptance policy. A later effort is intended to qualify LEU U-Mo fuel with uranium densities of 8-9 g/cm^3, for reactors requiring such high densities to convert.

   The initial schedule, which envisioned qualification of the LEU U-Mo fuel with 6 gU/cm^3 by the end of 2003, and with 8-9 g/cm^3 by the end of 2005, has suffered a slippage of more than one year. The cause of this slippage is directly linked to patents obtained by KAERI in 1999-2000 covering the use of spherical U-Mo particles in research reactor fuels. After some initial discussions on the subject by KAERI and ANL personnel, at the beginning of August 2001 the DOE General Counsel (DOE/GC) assumed total responsibility for resolving this issue between DOE and KAERI. BWXT was initially reluctant to produce a fuel covered by the KAERI patent but, responding to a letter by DOE/GC, it has recently agreed to fabricate two fuel elements needed to qualify LEU U-Mo dispersion fuels with a uranium content of 6 g/cm^3. To provide insurance against other problems that may be caused by the KAERI patent, approximately half of the plates in the two BWXT elements will be fabricated using non-spherical powder. Similarly, one or two fuel elements will be fabricated by the CNEA, in Argentina, using both spherical and non-spherical powders to qualify LEU U-Mo fuel with uranium density of 7 g/cm^3. Irradiation of these elements in the HFR-Petten reactor is expected to begin around March 2003. The good behavior of low enriched U-Mo fuel samples during irradiation provides convincing evidence that LEU U-Mo fuels with high uranium densities can be successfully qualified.

4. Cooperation with the Russian RERTR program has continued. The purpose of this program is to conduct the conversion studies, safety analyses, fuel development, and fuel tests needed to establish the technical and economic feasibility of converting Russian-supplied research and test reactors to the use of LEU fuels. Irradiation of five LEU UO_2-Al tube-type assemblies, fabricated by the Novosibirsk Chemical Concentrates Plant (NZChK) with a uranium density of 2.5 g/cm^3, was successfully concluded in the WWR-M reactor at the Petersburg Nuclear Physics Institute (PNPI), St. Petersburg. A new "universal" LEU U-Mo pin-type fuel [8], which could be used with minor modification to convert most Russian designed research and test reactors, has been developed by the A. Bochvar Institute for Inorganic Materials (VNIINM). 72 mini-pins have been fabricated with uranium densities of 4 g/cm^3 and 6 g/cm^3 for irradiation testing in the MIR reactor at the Russian Institute of Atomic Reactors (RIAR), Dimitrovgrad, and two full-size pin-type assemblies have been fabricated with uranium density close to 6 g/cm^3 for irradiation testing at PNPI. The irradiations are planned to begin in the spring of 2002.

5. Significant progress was achieved during the past year on several aspects of producing ^{99}Mo from fission targets utilizing LEU instead of HEU [9]. This activity is conducted in cooperation with several other laboratories including the Indonesian National Nuclear Energy Agency (BATAN), the Argentina Comisión Nacional de Energía Atómica (CNEA), MDS Nordion/AECL (Canada), and the Australian Nuclear Science and Technology Organization (ANSTO).

6. Improvements were made to the methods and codes that are used to study the design, performance and safety characteristics of research reactors. These improvements included upgrades of the

WIMS-ANL cross section generation code, the REBUS diffusion theory burnup code, and the codes used to determine thermal-hydraulic safety margins.

7. Several joint studies are in progress to facilitate reactor conversions or to improve utilization of LEU fuel in converted reactors. In particular, conversion studies continued for the WWR-SM reactor in Uzbekistan, the HFR-Petten reactor in the Netherlands, and the SAFARI-1 reactor in South Africa.

8. With the recent conversions of the R2-0 reactor in Sweden and of the ULRR in the U.S., 20 research reactors have been fully converted to LEU fuels outside the United States, including ASTRA (Austria), BER-II (Germany), DR-3 (Denmark), FRG-1 (Germany), IAN-R1 (Colombia), IEA-R1 (Brazil), JMTR (Japan), JRR-4 (Japan), NRCRR (Iran), NRU (Canada), OSIRIS (France), PARR (Pakistan), PRR-1 (Philippines), RA-3 (Argentina), R2 (Sweden), R2-0 (Sweden), SAPHIR (Switzerland), SL-M (Canada), THOR (Taiwan), and TRIGA II Ljubljana (Slovenia). Eleven research reactors have been fully converted in the U.S., including FNR, GTRR, ISUR, MCZPR, OSUR, RINSC, RPI, ULRR, UMR-R, UVAR, and WPIR. Seven foreign reactors, GRR-1 (Greece), HOR (Netherlands), La Reina (Chile), MNR (Canada), SSR (Romania), TR-2 (Turkey), and TRIGA II Vienna (Austria), have been partially converted. (ASTRA, DR-3, GTRR, ISUR, MCZPR, SAPHIR, and UVAR were shut down after conversion).

3. Planned Activities

The major activities that the RERTR Program plans to undertake during the coming year are listed below.

1. Continue postirradiation examination of all the U-Mo microplates and miniplates irradiated to date in the ATR, including plates containing monolithic LEU U-Mo fuel with a uranium density of 16 g/cm^3.
2. Continue out-of-pile characterization tests on the main fuel materials of interest, to assess their properties and likely performance.
3. In cooperation with fuel manufacturers, complete fabrication of full-size LEU fuel assemblies containing U-Mo dispersion fuels with uranium densities of 6 g/cm^3 and 7 g/cm^3 for irradiation testing in the HFR-Petten reactor.
4. Begin irradiation of full-size LEU fuel assemblies containing U-Mo dispersion fuels with uranium densities of 6 g/cm^3 and 7 g/cm^3 in the HFR-Petten reactor under prototypic conditions.
5. Continue LEU conversion feasibility studies for U.S. and foreign research reactors. Continue calculations and evaluations about the technical and economic feasibility of utilizing reduced-enrichment fuels in reactors that require such assistance, and in reactors of special interest.
6. In collaboration with the Russian RERTR program, continue to implement the studies, analyses, fuel development, and fuel tests needed to establish the technical and economic feasibility of converting Russian-supplied research and test reactors to the use of LEU fuels. Begin irradiation testing of pin-type mini-elements at RIAR and pin-type fuel assemblies at PNPI. Fabricate two prototype full-size pin-type fuel assemblies for irradiation testing in the WWR-SM reactor in Uzbekistan.
7. Continue development of viable processes based on LEU for the production of fission ^{99}Mo in research reactors in cooperation with several current and future ^{99}Mo producers.

3. Summary and Conclusion

- A patent issue with KAERI has caused a slippage in the schedule for qualification of LEU U-Mo dispersion fuels, but all other activities have proceeded as planned, with positive results. The RERTR program plans to continue to concentrate its fuel development effort on fuels based on U-Mo alloys with two major thrusts:

(1) To develop, demonstrate, and qualify LEU U-Mo fuels with uranium densities of up to 6 g/cm^3 that can replace silicide fuels in current use. Qualification of these fuels is scheduled for mid-2005.

(2) To develop, demonstrate, and qualify LEU U-Mo fuels with uranium densities in the 8-9 g/cm^3 range, to enable conversion of reactors that cannot be converted today. Qualification of these fuels is scheduled for mid-2007.

- Excellent progress was made in the development of suitable commercial processes to produce fission ^{99}Mo using LEU targets.
- The Russian RERTR program has made excellent progress. In particular, VNIINM has developed a "universal" LEU U-Mo fuel pin design that could be used, with minor modifications, to convert most Russian-designed research reactors.
- The events of September 11, 2001 have made the task of minimizing and eventually eliminating worldwide use of HEU for civilian applications more important and pressing than ever. We believe that this goal is achievable and intend to do our best, with the collaboration of the many participants in the international RERTR effort, to attain it in the shortest possible time.

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